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SOME DIGESTIBILITY TRIALS ON INDIAN FEEDING STUFFS

BY

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Agricultural Chemist to Government, Punjab

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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[Received for publication on 2nd November, 1923.]

Introductory.

The experiments recorded in the following paper are the result of an endeavour to obtain information on the feeding values of some of the commoner Indian foodstuffs as shown by actual digestibility trials.

Although a large number of analyses of feeding stuffs have been made in this country, notably by Leather,[1] yet little or nothing has yet been done to study systematically and side by side the values of feeding stuffs as shown by chemical analysis and their values as indicated by digestion trials on animals.

Chemical analysis by itself, while giving an indication of the actual amounts of various food ingredients present, such as the fats, proteins, carbohydrates, etc., can tell us but little of the way in which any particular animal will be able to utilize them for its general metabolism ; and a foodstuff, the chemical analysis of which shows a high content of fats, carbohydrates and proteins, may be of less value to an animal than one with a " lower chemical value " if the contents of the latter are more digestible than those of the former.

In times of scarcity it is a matter of great necessity to find materials not ordinarily used, which may be utilized to supplement an animal's ration.

[1] Leather, J. W. *Agri. Ledger*, 10 (1901) and 7 (1903).

Such a case presented itself in the Punjab when the first author was asked in 1921 to report on the value of *shisham* (*Dalbergia sissoo*) leaves as a supplementary article of diet for animals.

The analysis of fresh *shisham* leaves collected in July of that year showed them to possess a feeding value comparable to that of oats, but when feeding trials were undertaken, an entirely different picture was presented, animals not being able to tolerate more than five to six lb. daily with impunity, as will be shown later.

The problem before us is to determine what percentage of the various ingredients which chemical analysis reveals, can be digested and utilized by the animal, and presents different aspects according to whether we are dealing with growing or mature animals.

In the case of mature animals the digested food material has only to be utilized for external and internal work and for the general wear and tear of the organism, whereas young animals have in addition to lay on extra tissue material, and in this latter connection it is the *type* or quality of food material which is most important, quite apart from its quantity and digestibility. Whereas the fats and carbohydrates are of a comparatively simple chemical composition and few in number, and may within certain limits be considered of equal value for the nutrition of growing or mature animals, the protein part of the food is much more complicated. With growing animals the most important point is, not the actual quantity of protein which the food contains, but its quality, or, in other words, the nature of the amino acids into which the protein is broken down in the course of digestion.

If a growing animal is fed a standard ration in which all of the protein is fed in the form of Indian corn or maize, growth rapidly comes to a standstill and ultimately death ensues, or again if a pregnant cow is fed such a diet, the calf will be born prematurely, be imperfectly formed and but short-lived. In both cases deficiency in the diet is due to the fact that certain amino acids, *viz.*, tryptophane and glycine, which are absolutely necessary for the formation of new growing tissues, are absent. Thus studies in animal foodstuffs should be conducted along three main lines. First, the crude chemical analysis carried out in the laboratory to give us a quantitative picture; secondly, digestion trials which should indicate how far the animal can digest these same ingredients; and, thirdly, what may be termed the biological investigation of the proteins present, and their value as determined by experiments on young growing animals. All these are highly important both from a nutritive and from an economic standpoint, the problem presenting different aspects according to whether we are dealing with young or mature animals. A glance

at the work which has already been done in Europe and America will indicate the magnitude of the problems to be tackled, but it does not follow that results obtained from any of the above mentioned lines of enquiry obtained in one country will hold good in another in which climatic and other conditions vary widely. Hence it is of the utmost importance for Indian agriculture that systematic research along the lines indicated should be attempted.

It is felt that some apology is perhaps needed for presenting some of the results obtained, results which though negative and impossible in themselves nevertheless give us information of a very positive kind. Such results will be indicated and discussed in the context; for example, negative digestibility coefficients and coefficients greater than one hundred.

No mention will be made here of the extensive subject of vitamines as the investigation was confined to chemical analysis and digestibility coefficients.

It was a matter of great regret that only two animals were available for the work in 1921-22, both of which were rather old and feeble, and the extraordinary results obtained on the *bhusa* diet alone, which must also have affected the succeeding diets, led to a repetition of the *bhusa* trials during the winter of 1922-23 on better conditioned animals, but unfortunately again only two were available.

Too much emphasis cannot be laid on the fact that work of this description must be carried on with as large a number of animals as possible, though this entails a vast amount of work in supervision and analysis.

Object and method of the experiments.

The object in view has been to determine the quantitative feeding value and the digestibility coefficients of *bhusa*, gram, maize, and fresh *shisham* leaves. The *bhusa* and *shisham* leaves may be considered as roughages, while gram and maize are concentrates. An attempt was made to determine the digestibility coefficient of *bhusa* alone, and better results would perhaps have been obtained had the animals been younger and in better condition. The method employed with such a roughage as *bhusa* was to analyse both the *bhusa* given and the dung voided during the experimental period and calculate the digestibility coefficients directly from the results.

This is very simple but the digestibility of concentrates by herbivora is more complicated since they cannot be fed as the sole feed of these animals. They must therefore be fed along with a known amount of a roughage whose digestibility by the same animal has been determined in a preceding period. From the digestibility of the total ration and the known digestibility of the

roughage that of the concentrate is obtained by means of a second calculation by difference.

The sequence of diets employed was :—*Bhusa*, *bhusa* and gram, *bhusa* and maize, and *bhusa* and *shisham* leaves. While the *shisham* leaves may be considered as a roughage it was impossible to feed animals on the fresh leaves alone, not more than five to six pounds being acceptable even when fed with *bhusa*. The animals were fed for a period of 10 days on each diet under investigation before the actual chemical and other data were determined (in order to remove the effects of previous feeding).

The feeding of the first preparatory period was commenced on the 29th November, 1921, and carried on till the 7th December for both animals, Sawa and Gora by name. During the period of 9 days *bhusa* alone was given, and the amount of *bhusa* eaten, the dung voided, and the daily weights of the animals were carefully recorded.

The actual experimental period was from the 7th December till the 23rd during which time the same records were made and detailed analyses were made of the daily *bhusa* given and the dung voided.

We were thus able to determine the total quantities of each food constituent, such as fats, proteins, etc., present both in the food eaten and in the dung voided, although, as will be pointed out later, some very abnormal results were obtained.

Method of feeding the animals. The animals were kept in a stable and the food placed in zinc troughs so constructed that none was lost, and each animal was confined to its own trough. About 16 lb. of *bhusa* was finely sieved in order to separate dust, and this was placed in the troughs in three separate parts, in the morning, at noon and in the evening, and on the following morning any residue left was collected and carefully weighed. The animals were watered twice daily, once after the daily weighing which took place before they were fed, and once after the evening meal. Common salt was always available. The dung was collected in bags fixed on to the animal so arranged that no contamination with urine took place—as shown in Fig. 1—both morning and evening, and the daily yield carefully sampled and analysed. During the course of the experiments the animals were stall-fed and did no work other than walking up to the weigh-bridge 200 yards away and back.

Period of feeding on bhusa. During this period of 17 days Sawa ate 166 lb. of *bhusa* corresponding to 156·5 lb. of dry matter, the analysis of which is shown in Tables I and Ia, the amount of dung collected being 381 lb. corresponding to 83 lb. of dry matter. The analyses of dung are also shown. The corresponding figures for Gora were :—*Bhusa* eaten 148 lb. corresponding to

139·6 lb. of dry matter and the total quantity of dung voided was 308·5 lb. corresponding to 77·12 lb. of dry matter. From the total dry matter in the

FIG. I. Bullocks Sawa and Gora with harness for collecting dung.

bhusa and that in the dung voided the digestibility coefficient of the *bhusa* found is 46·93 for Sawa, and 44·76 for Gora.

The digestibility coefficients of the various ingredients of the *bhusa* were also determined from the analyses of *bhusa* and dung, and some rather extraordinary results were obtained. From the tables we notice that the ash, fat and protein which are present in the original *bhusa* all show negative digestibility coefficients, indicating that they are present in greater quantities in the fæces than in the food given. This is intelligible, when dealing with *bhusa* such as that used which contains but a small percentage of those substances, when it is remembered that certain excretory products from the animals are also voided in the fæces which have been ignored in the experiment but which are obviously included in the indigestible fraction of the food.

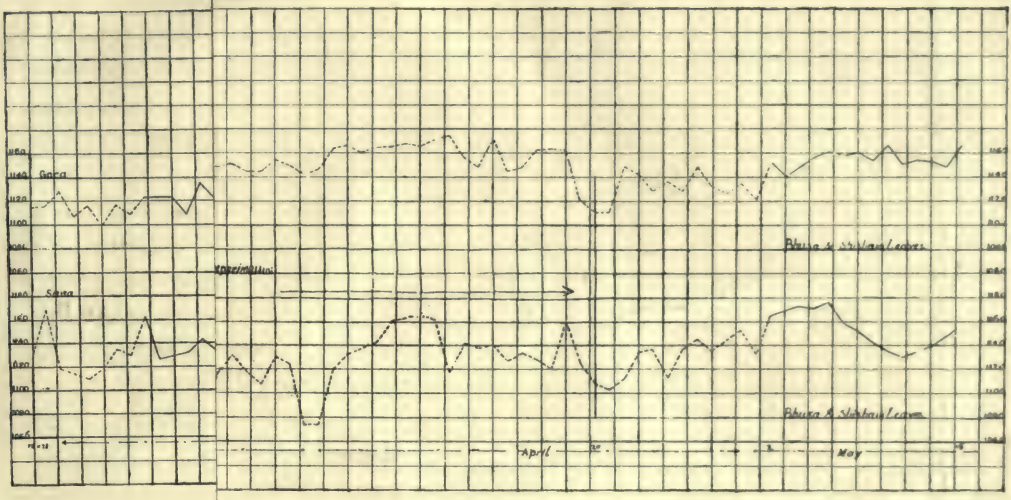
The crude fibre and nitrogen-free extract which are present in greatest proportions in the *bhusa* show no such anomalies, as neither of these would be derived from the excretory products of the animal. Such negative results are not uncommon, when investigating substances present in only small quantity, and, as Armsby[1] has shown, when investigating the coefficients for concen-

[1] Armsby. Errors of digestibility. *Amer. Jour. Sci.*, **29**, 355, 1885.

trates mixed with roughage the range of uncertainty introduced may be very great and such negative results may occur.

Both animals show these abnormalities to a similar degree. An interpretation of these figures indicates that the crude fibre and carbohydrates are between 50 and 60 per cent. digestible, the digestibility of the very small percentages of fats and proteins being overmasked by the presence of excretory products contaminating the fæces. In view of the negative figures obtained from these two animals it was decided to repeat this trial, using better animals, and the test was accordingly carried out in January and February of the following year, the results of which will be recorded in full detail later.

Bhusa and gram trials. From the 24th December until the 15th January, the transition period, the animals were fed on 4 lb. of ground gram per day in addition to *bhusa*. The gram, in a coarsely crushed condition, was fed to the animals in the morning, mixed with some *bhusa*, so that practically the whole of the *bhusa* and the gram was eaten. Additional *bhusa* up to a total of 16 lb. was then fed to them during the rest of the day. From the 16th to the 29th, the experimental period, the animals were fed 4 lb. of gram daily, all of which was eaten, and 16 lb. of *bhusa*. During these 14 days each animal ate 56 lb. of gram. Sawa ate in addition 182 lb. of *bhusa* corresponding to 171·6 lb. of dry matter, whilst Gora ate 164·5 lb. of *bhusa* corresponding to 155·1 lb. of dry matter. Sawa excreted 471·5 lb. of dung corresponding to 90·34 lb. of dry matter, while Gora excreted 412·5 lb. of dung corresponding to 94·75 lb. of dry matter. From these two series of data the digestibility coefficient of the combined feed in the case of Sawa was found to be 59·46, whilst in the case of Gora it was 54·07 on the dry matter of the combined feed. In Tables II and IIA are shown the analyses of the *bhusa*, gram and dung and the digestibility coefficients of the various ingredients of the combined feed. In view of the negative values given for the *bhusa* figures it seems perhaps invidious to work out the coefficients of the gram alone. If, however, we assume that the digestibility of the *bhusa* was unaltered by the addition of the gram, an assumption which is not strictly justified, it is possible to compute how much of each kind of digestible matter, protein, crude fibre, nitrogen-free extract, etc., in the total ration, was derived from the *bhusa*; the remainder must therefore have come from the gram. The percentage of digestibility can thus be determined. These figures are shown in Tables II and IIA. Turning to these tables we notice that some of the figures are very high, being above 100 per cent., the interpretation of which is that the influence of the gram on the *bhusa* is to render some of the ingredients of the latter still more digestible in the combined diet than alone, this added digestibility thus being added on to that of the gram. In the


Ganga
Sarda
Indus
Bhutia & Sikkim Lepchas
Bhutia & Sikkim Lepchas
April
May

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case of Sawa, the gram as a whole (to a small extent) and the ash and the fibre (to a greater extent, as they are present in small amount) all show this effect and to a certain degree also the nitrogen-free extract, whereas in the case of Gora these figures are not so high and approximate more nearly to what one would expect. It may be mentioned that during the course of the experiment Gora was in better physical condition than Sawa besides being somewhat younger.

The bhusa and maize trial. From January 29th to February 9th was a transition period during which 4 lb. of maize and 16 lb. of *bhusa* were fed to the animals daily. The maize was fed by grinding it up, moistening it and mixing it with half the daily ration of *bhusa* and fed at 8 A.M., the remaining *bhusa* being fed at 6 P.M. in the evening. On February 9th the experimental period commenced and continued until February 22nd, the same feeding régime being observed. It was found that by mid-day the whole of the maize given in the morning meal with the mixed *bhusa* was entirely eaten, any residue being negligible. During this period each animal was fed 56 lb. of maize corresponding to a total of 50·97 lb. of dry matter. Sawa ate in addition 122 lb. of *bhusa* corresponding to 115 lb. of dry matter and Gora ate in addition 121 lb. of *bhusa* corresponding to 114 lb. of dry matter. During this period Sawa voided 309 lb. of dung corresponding to 60·7 lb. of dry matter and Gora 280·5 lb. corresponding to 70·5 lb. of dry matter. The digestibility coefficient of the combined feed in the case of Sawa was 63·4 and the digestibility coefficient in the case of Gora was 57·28, a decided increase over the last two coefficients obtained. The results are shown in Tables III and IIIA. Looking at the digestibility coefficients of the individual constituents of the combined diet we notice that only the ash (in the case of Sawa) presented an abnormal figure (being negative), whilst those of Gora all show a positive value. When, however, we come to compute the digestibility coefficients of the maize as a whole and of its various constituents, we again find some very high figures. The maize as such shows 100 per cent. digestibility whilst the figures for the ash and crude fibre are considerably higher as they are also in the case of gram. This can only mean that the continued effect of feeding the animals on a partly cereal diet is having a considerable influence on the digestibility of the *bhusa* fed.

At the end of this period on the 22nd February the animals were returned to the farm until the 20th April, during which time a record of their weights was kept as shown in Fig. 2. They were fed on ordinary farm rations—wheat *bhusa*, *senji* (*Melilotus parviflora*), cane tops (*Saccharum officinarum*) and gram (*Cicer arietinum*)—and did very little work during the whole of this period.

The bhusa and shisham period. The period from the 20th April to the 1st May was preparatory during which time the animals were fed as much *shisham* leaves for the first few days as they cared to eat; after which the amount they were allowed to eat was restricted to about 5 to 6 lb. a day. They were also given in addition from 8 to 10 lb. of *bhusa* daily. During this preparatory period it was found that the animals ate the leaves with great avidity to begin with, but their appetite for large quantities soon diminished and they began to pass watery voidings. On account of this, as mentioned above, the daily ration of leaves was reduced to 6 lb. and one oz. of ammonium carbonate per day was administered for 4 days, as a result of which treatment the animals were rapidly cured. During the preparatory period the daily body weights were kept and fodder residues were carefully noted, but no dung was collected. The actual experimental period was from the 2nd to the 15th May when fresh *shisham* leaves were mixed with *bhusa* and fed to the animals in the morning; more *bhusa* being again fed to them in the evening but without leaves. No food was given during the night. The animals were watered 3 times a day, first after weighing, at noon, and between 4 and 5 P.M. During this period the animals ate the whole of the *shisham* leaves that were given; Sawa ate 64 lb. of *shisham* corresponding to 18·21 lb. of dry matter, and in addition 121·5 lb. of *bhusa* corresponding to 114·6 lb. of dry matter. During the same time Gora ate 68 lb. of *shisham* corresponding to 19·35 lb. of dry matter and 137·5 lb. *bhusa* corresponding to 130 lb. of dry matter. The complete data are shown in Tables IV and IVA. Sawa during this period voided 327 lb. of dung corresponding to 54 lb. of dry matter and Gora 308 lb. corresponding to 63 lb. The digestibility coefficient of the combined feed in the case of Sawa was 59·2 and in the case of Gora 57·6. Turning now to the tables we notice that the figures for the individual constituents of the combined diet are all perfectly normal and agree fairly closely for the two animals, there being no very wide discrepancies between them. When, however, we come to calculate the co-efficients for the individual constituents of the *shisham* leaves and the *shisham* as a whole, we again notice very abnormal figures. The coefficients for the *shisham* work out at 136 per cent. in one case and 143 per cent. in the other, whereas in both cases the figures for ash, fats, crude fibre, proteins and nitrogen-free extract are very high, and can in no wise be taken as absolute. These are very interesting. Had the figures for the *shisham* shown a negative value we would have interpreted it as meaning that the leaves could not be utilized by the animals, but being so highly positive, although the figures offer no actual criterion as to the true digestibility coefficient for the *shisham*, they yet

indicate that the very low negative values obtained when *bhusa* is fed alone are being ameliorated and converted into positive products, or, in other words, that an admixture of *shisham* with *bhusa* considerably augments not only the digestibility of the combined feed but also renders the *bhusa* itself more digestible.

Some investigations on feeding silaged *shisham* leaves have been carried out by Messrs. Branford and Sewell,[1] at the Government Cattle Farm, Hissar, and the conclusions which they come to are that animals readily eat *shisham* leaves which have been silaged, and that this material forms a very valuable adjunct to *bhusa* in times of fodder scarcity. These gentlemen have not carried out detailed observations in regard to the weights of the animals day by day nor were they able to carry out chemical analyses. Their results are in harmony with the practical experience of zemindars who find that animals will readily eat and tolerate small quantities of fresh *shisham* leaves, whereas larger amounts produce digestive disturbances. The effect is not so much poisonous but rather due to the fact that the young leaves contain some bitter and astringent principles which have a deleterious effect on the digestive tract, but this effect may be remedied by keeping the quantity of fresh leaves eaten down to about 6 lb. per diem, and would appear to diminish as the leaves get older. The experiments carried out at Hissar with siloed leaves seem to indicate that if the leaves are properly siloed the effect of the fermentative and other enzymic actions is to destroy the bitter principles mentioned above, and that siloed leaves would not only be less injurious to animals but would also be able to be fed in somewhat greater bulk to supplement ordinary rations. Experiments are in course of progress to investigate the alterations in the chemical ingredients of *shisham* leaves during the siloing period and it is hoped that these will be followed up by feeding and digestion trials.

The animals' weights during the course of the trials.

Each animal was weighed daily throughout the experimental and intermediate non-experimental periods, and the weights are plotted in Figs. 2 and 3, with explanatory notes. From November 29th, 1921, to December 23rd, when the animals were on a *bhusa* diet alone it will be noted that the initial and final weights in the case of Sawa were 1,130 lb. and 1,126 lb., whereas the highest and lowest weights recorded were 1,168 and 1,097 lb., the corresponding figures for Gora being 1,114 and 1,104 lb., and 1,134 lb. and 1,089 lb.

[1] Branford, R., and Sewell, E. Feeding Experiments at Govt. Cattle Farm, Hissar. *Pusa Agri. Res. Inst. Bull.* 130.

The fluctuations were greatest in the case of Sawa, the less fit animal of the two, and we note that both the animals were of approximately the same weight at the beginning and end of the trials. A true maintenance ration is one during the feeding of which the general metabolism is in a state of balanced equilibrium, the body weight being maintained constant.

The object of the trials was not primarily to determine maintenance rations and, on first appearances, if the initial and final weights alone are considered, the *bhusa* would appear to approximate to a maintenance ration. No account, however, has been taken of the nitrogen excreted in the urine and no attempts made to determine the nitrogen balance sheet on the *bhusa* diet.

The important point which these weights as recorded indicate is that it is quite inadequate to weigh an animal on the first and last day of a trial. Retention of fæces and excessive intake and output of water may entirely mask the true state of the animal's weight. In view of the results obtained on the digestibility coefficients for the *bhusa*, this cannot be considered a maintenance ration for these two animals. It is only by taking a full daily record of all data that we are able to obtain an approximately true metabolic picture.

From the 23rd December when the *bhusa* and gram diet was substituted until the 29th January when gram was replaced by maize we again notice that the initial weight was preserved in Sawa's case and somewhat exceeded in Gora's with rather heavy fluctuations in between. The curves up to the end of the period of feeding on *bhusa* and maize on February 22nd tell their own story. From February 22nd to the 19th April both animals were put on an ordinary diet (prior to feeding with *shisham* leaves) which consisted of *bhusa*, *senji*, maize, cane tops, etc. Their respective weights on February 22nd being 1,112 and 1,082 lb. and on April 19th 1,124 and 1,120 lb., the intervening weights being shown on the curves. From April 20th to May 2nd was a preparatory period and from May 2nd to May 15th the experimental period of *bhusa* and *shisham* leaves, and it will be noted that the weights of both animals were well up at the end of the trial, being 1,156 lb. and 1,166 lb. respectively, against 1,130 and 1,114 lb. at the very commencement.

The somewhat extraordinary results obtained in the digestibility coefficients for the fats, carbohydrates and proteins in the *bhusa* trials, which formed the basis of the experiment, undoubtedly vitiated later results, and it was decided to repeat the trials on *bhusa* in the following year (1922-23). The original *bhusa* was carefully reanalysed but no discrepancies were found.

The same two animals could not be employed as they had been sold, but two others were procured of about the same age, and in much better physical condition. The *bhusa* which was fed to these animals, named Nila and Mina, was from the 1922 harvest and was much richer according to chemical analysis than that fed in the previous year, the percentage of proteins being practically double. Analyses of the *bhusa* used in the second year's trials are shown in Tables V, VA, VI and VII. The bullocks prior to the experimental trials had been fed on ordinary farm rations and the preparatory feeding period on *bhusa* alone was commenced on the 12th January, 1923, whilst the actual experiment began on the 22nd January. The bullocks were weighed daily at 7 A.M., but unfortunately the weigh-bridge broke on the 29th. Water was given twice daily, once in the morning just after weighing and once in the evening, and salt was kept in the feeding troughs throughout the whole experiment. The total quantity of *bhusa* to be given to each bullock during the day was weighed in the morning and fed in three lots at equal intervals. Dung was collected twice a day, morning and evening, and the bullocks did no work during the course of the experiment apart from walking to and from the water tank and the weigh-bridge. The health of the two animals remained quite good throughout the whole of the experimental period. The analytical and recorded data for the two animals are shown in Tables V and VA, and the analysis of the *bhusa* used in the 1922 and 1923 trials with albuminoid ratio and food units in Table VI.

Body weights as recorded daily are plotted in Fig. 3.

During this period it was noticed again that while there are very considerable fluctuations in the body weights from day to day the average weight was well maintained, and the figures obtained emphasize the importance of taking the weights every day and not only on the first and last days of any particular experiment, if we want to glean correct information as to the effect of a diet on the body weight of an animal. Bullock number 1 (Nila) consumed during the experimental period of 12 days, from the 23rd January to 4th February, 129 lb. of *bhusa* corresponding to 118 lb. of dry matter, the dung voided being 306 lb. corresponding to 52·17 of dry matter, showing a digestive coefficient for the *bhusa* of 55·78. In the case of animal number 2 (Mina), the digestive coefficient of the *bhusa* works out at 61. From the analysis of *bhusa* and dung the digestibility coefficients for the individual constituents were worked out as shown with a very tolerable degree of similarity in the case of the two animals, and furthermore no abnormal figures present themselves, all the figures being well on the positive side with no negative ones such as were obtained in the previous

year's trials. This is undoubtedly due to the fact that the animals were in far better condition and also that the *bhusa* was much richer in nutritive contents. It is interesting to compare the figures obtained in these *bhusa* trials with the figures of a similar experiment conducted with hay as given by Armsby. Table VII shows such a comparison of figures from one of Armsby's experiments with the figures obtained from the animal Mina in this second set of *bhusa* trials. There is no doubt whatever that the age and

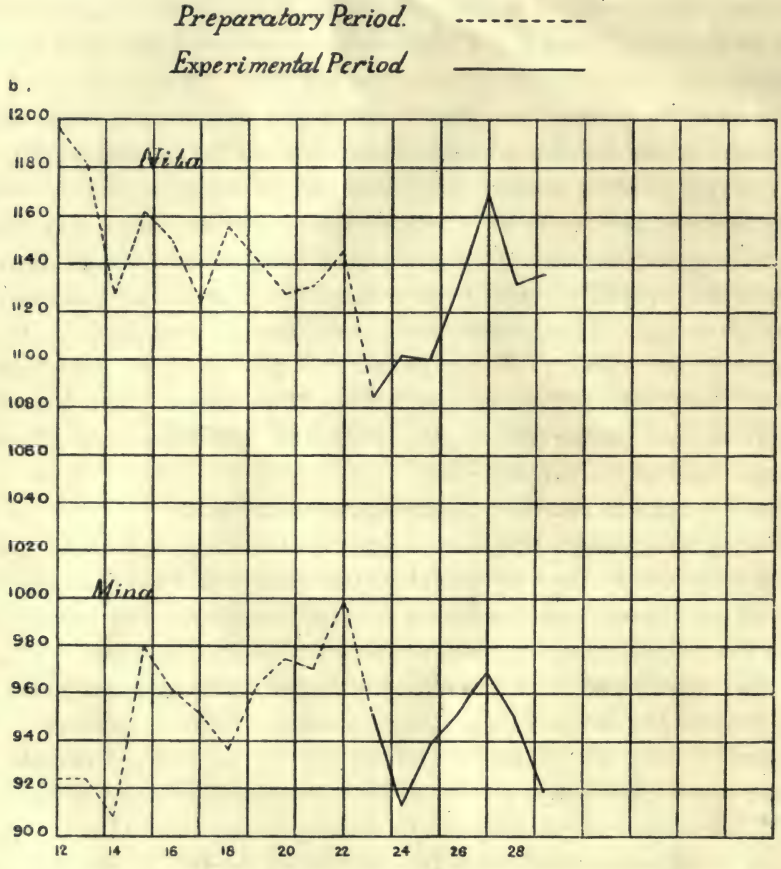

FIG. 3.

condition of the animals under trial very materially affect the results which will be obtained, and that the higher the percentage of the various nutritive ingredients present in a roughage such as *bhusa*, the less likelihood is there of obtaining absurd results such as were obtained in the first trials with *bhusa*.

These results though incomplete in themselves are presented as it is felt that they are of decided interest as indicating the initial lines along which work on feeding stuffs in India should proceed.

They will be continued and extended as opportunity offers.

Digestibility Experiments.

Table I.

Feed		*Bhusa* (from wheat) alone.
Animal		Sawa.
Period		7th to 23rd December, 1921.
Bhusa given ..	..	266 lb.
Bhusa residue ..	..	100 „
Bhusa eaten ..	..	166 „ = 156·50 lb. dry matter.
Dung ..	..	381 „ = 83·06 „ „ „
Digestibility coefficient	..	= 46·93.

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Dung	78·20	21·80	4·50	0·32	6·68	1·07	9·23

Actual quantities of different constituents.

In *bhusa* given ..	..	156·50	12·58	1·20	66·18	2·86	73·70
In dung voided ..	..	83·06	17·14	1·22	25·45	4·08	35·17
Bhusa digested (by difference) ..	..	73·44	–4·56	–0·02	40·73	–1·22	38·53
Digestibility coefficients	..	46·93	–36·25	–1·67	61·53	–42·65	52·26

Digestibility Experiments.

Table Ia.

Feed	..	..	*Bhusa* (from wheat) alone.
Animal	..	..	Gora.
Period	..	..	7th to 23rd December, 1921.
Bhusa given	..	..	262 lb.
Bhusa residue	..	..	114 ,,
Bhusa eaten	..	..	148 ,, = 139·60 lb. dry matter.
Dung	..	..	308·5 ,, = 77·12 ,, ,, ,,
Digestibility coefficient		..	= 44·76.

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Dung	75·00	25·00	5·01	0·36	7·81	1·20	10·62

Actual quantities of different constituents.

In *bhusa* given ..	..	139·60	11·22	1·07	59·00	2·55	65·71
In dung voided ..	..	77·12	15·46	1·11	24·10	3·70	32·76
Bhusa digested (by difference) ..	..	62·48	–4·24	–0·04	34·90	–1·15	32·95
Digestibility coefficients	..	44·76	–37·79	–3·74	59·13	–45·09	50·13

Digestibility Experiments.

Table II.

Feed .. .. *Bhusa* and gram.
Animal .. .. Sawa.
Period .. .. 16th to 29th January, 1922.

Bhusa given	224 lb.			
Bhusa residue	42 „			
Bhusa eaten	182 „	= 171·60	lb.	dry matter.
Gram eaten	56 „	= 51·30	„	„ „
Total ..		222·90	„	„ „
Dung	471·5 lb.	= 90·34	„	„ „
Digestibility coefficient of combined diet		= 59·46		
„ „ „ gram		= 101·40		

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Gram	8·42	91·58	3·29	2·62	6·90	18·88	59·89
Dung	80·84	19·16	3·68	0·42	5·35	1·45	8·26

Actual quantities of different constituents.

In *bhusa* given	171·60	13·80	1·31	72·56	3·13	80·81
In gram given	51·30	1·84	1·47	3·86	10·57	33·54
In total feed given	222·90	15·64	2·78	76·42	13·70	114·35
In dung voided	90·34	17·36	1·98	25·23	6·84	38·95
Total feed digested (by difference)	132·56	–1·72	0·80	51·19	6·86	75·40
Total digested from *bhusa*	80·54	–5·00	–0·02	44·62	–1·34	42·24
Total digested from gram	52·02	3·28	0·82	6·57	8·20	33·16
Digestibility coefficients of constituents of combined feed	59·46	–11·00	28·78	66·98	50·07	65·92
Digestibility coefficients of constituents of gram	101·40	178·30	55·78	170·20	77·58	98·85

Digestibility Experiments.

Table IIa.

Feed .. .. *Bhusa* and gram.
Animal .. .. Gora.
Period .. .. 16th to 29th January, 1922.

Bhusa given ..	.. 224 lb.			
Bhusa residue ..	.. 59·5 „			
Bhusa eaten ..	.. 164·5 „	= 155·10	lb.	dry matter.
Gram eaten ..	.. 56·0 „	= 51·29	„	„ „
Total ..		206·39	„	„ „
Dung ..	.. 412·5 „	= 94·75	„	„ „
Digestibilty coefficient of combined diet		= 54·07		
„ „ „ gram		= 82·30		

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Gram	8·42	91·58	3·29	2·62	6·90	18·88	59·89
Dung	77·03	22·97	4·23	0·48	5·91	1·87	10·48

Actual quantities of different constituents.

In *bhusa* eaten	155·10	12·47	1·18	65·59	2·83	73·04
In gram eaten	51·29	1·84	1·47	3·86	10·57	33·54
In total feed eaten	206·39	14·31	2·65	69·45	13·40	106·58
In dung voided	94·75	17·45	1·98	24·38	7·71	43·23
Total digested (by difference)	111·64	–3·14	0·67	45·07	5·69	63·35
Total digested from *bhusa*	69·42	–4·71	–0·04	38·80	–1·28	36·61
Total digested from gram	42·22	1·57	0·71	6·27	6·97	26·74
Digestibility coefficients of constituents of combined feed	54·07	–21·94	25·28	64·89	42·46	59·44
Digestibility coefficients of constituents of gram	82·30	85·30	48·30	162·40	65·95	79·72

Digestibility Experiments.

Table III.

Feed .. .. *Bhusa* and maize.
Animal .. .. Sawa.
Period .. .. 9th to 22nd February, 1922.

Bhusa given	142 lb.				
Bhusa residue	20 „				
Bhusa eaten	122 „	=	115·03	lb.	dry matter.
Maize eaten	56 „	=	50·97	„	„ „
Total ..			166·00	„	„ „
Dung	309 „	=	60·72	„	„ „
Digestibility coefficient of combined diet		=	63·40		
„ „ „ maize		=	100·65		

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Maize	8·99	91·01	1·95	3·51	1·84	9·31	74·40
Dung	80·35	19·65	3·42	0·45	5·30	1·62	8·86

Actual quantities of different constituents.

In *bhusa* eaten ..	..	115·03	9·25	0·88	48·64	2·10	54·17
In maize eaten ..	..	50·97	1·09	1·97	1·03	5·21	41·67
In total feed eaten ..	..	166·00	10·34	2·85	49·67	7·31	95·84
In dung voided ..	..	60·72	10·57	1·39	16·38	5·01	27·38
Total feed digested (by difference) ..	..	105·28	–0·23	1·46	33·29	2·30	68·46
Total digested from *bhusa*	..	53·98	–3·35	–0·01	29·93	–0·90	28·31
Total digested from maize	..	51·30	3·12	1·47	3·36	3·20	40·15
Digestibility coefficients of constituents of combined feed ..	..	63·40	–22·24	51·22	67·00	31·45	71·41
Digestibility coefficients of constituents of maize ..	..	100·65	286·20	74·60	326·20	61·40	96·34

Digestibility Experiments.

Table IIIa.

Feed .. .. *Bhusa* and maize.
Animal .. .. Gora.
Period .. .. 9th to 22nd February, 1922.

Bhusa given ..	.. 141 lb.				
Bhusa residue ..	.. 20 „				
Bhusa eaten ..	.. 121 „	= 114·09	lb.	dry	matter.
Maize eaten ..	.. 56 „	= 50·97	„	„	„
Total ..		165·06	„	„	„
Dung ..	.. 280·5 „	= 70·51	„	„	„
Digestibility coefficient of combined diet		= 57·28			
„ „ „ maize		= 85·29			

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Maize	8·99	91·01	1·95	3·51	1·84	9·31	74·40
Dung	74·86	25·14	3·39	0·45	6·49	1·84	12·97

Actual quantities of different constituents.

In *bhusa* eaten ..	..	114·09	9·17	0·87	48·25	2·08	53·73
In maize eaten ..	..	50·97	1·09	1·97	1·03	5·21	41·67
In total feed eaten ..	..	165·06	10·26	2·84	49·28	7·29	95·40
In dung voided ..	..	70·51	9·51	1·26	18·21	5·16	36·38
Total feed digested (by difference) ..	..	94·55	0·75	1·58	31·07	2·13	59·02
Total digested from *bhusa*	..	51·07	–3·47	–0·03	28·53	–0·94	26·94
Total digested from maize	..	43·48	4·22	1·61	2·54	3·07	32·08
Digestibility coefficients of constituents of combined feed ..	..	57·28	7·31	55·62	63·03	29·21	61·85
Digestibility coefficients of constituents of maize ..	..	85·29	387·10	81·70	246·60	58·91	76 98

Digestibility Experiments.

Table IV.

Feed .. .. *Bhusa* and *shisham* leaves.
Animal .. .. Sawa.
Period .. .. 2nd to 15th May, 1922.

Bhusa given	142 lb.			
Bhusa residue	20·5 „			
Bhusa eaten	121·5 „	= 114·56	lb.	dry matter.
Shisham leaves eaten ..	64 „	= 18·21	„	„ „
Total ..		132·77	„	„ „
Dung	327 „	= 54·18	„	„ „
Digestibility coefficient of combined diet		= 59·20		
„ „ „ *shisham* leaves		= 136·25		

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Shisham leaves ..	71·54	28·45	2·95	1·13	5·59	5·11	13·68
Dung .. .	83·43	16·57	2·43	0·23	5·70	1·06	7·15

Actual quantities of different constituents.

In *bhusa* eaten	114·56	9·21	0·87	48·44	2·09	53·95
In *shisham* leaves eaten. ..	18·21	1·89	0·72	3·58	3·27	8·76
In total feed eaten	132·77	11·10	1·59	52·02	5·36	62·71
In dung voided	54·18	7·95	0·75	18·64	3·47	23·38
Total feed digested (by difference)	78·59	3·15	0·84	33·38	1·89	39·33
Total digested from *bhusa*	53·78	–3·34	–0·01	29·81	–0·89	28·20
Total digested from *shisham* leaves	24·81	6·49	0·85	3·57	2·78	11·13
Digestibility coefficients of constituents of combined feed	59·20	28·38	52·83	64·16	35·25	62·71
Digestibility coefficients of constituents of *shisham* leaves	136·25	343·40	118·10	99·71	85·01	127·00

Digestibility Experiments.

Table IVa.

Feed ..	.. *Bhusa* and *shisham* leaves.			
Animal ..	.. Gora.			
Period ..	.. 2nd to 15th May, 1922.			
Bhusa given ..	.. 150 lb.			
Bhusa residue ..	.. 12·5 „			
Bhusa eaten ..	.. 137·5 „	= 129·65 lb.	dry matter.	
Shisham leaves eaten	.. 68 „	= 19·35 „	„	„
Total ..		149·00 „	„	„
Dung ..	.. 308 „	= 63·20 „	„	„
Digestibility coefficient of combined diet		= 57·59		
„ „ „ *shisham* leaves		= 143·35		

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Shisham leaves ..	71·54	28·45	2·95	1·13	5·59	5·11	13·68
Dung	79·48	20·52	2·60	0·27	7·48	1·09	9·08

Actual quantities of different constituents.

In *bhusa* eaten ..	129·65	10·42	0·99	54·82	2·36	61·05
In *shisham* leaves eaten ..	19·35	2·01	0·77	3·80	3·48	9·30
In total feed eaten ..	149·00	12·43	1·76	58·62	5·84	70·35
In dung voided ..	63·20	8·01	0·83	23·04	3·36	27·97
Total feed digested (by difference) ..	85·80	4·42	0·93	35·58	2·48	42·38
Total digested from *bhusa*	58·06	–3·94	–0·04	32·42	–1·06	30·61
Total digested from *shisham* leaves ..	27·74	8·36	0·97	3·16	3·54	11·77
Digestibility coefficients of constituents of combined feed ..	57·59	35·56	52·85	60·68	42·45	60·23
Digestibility coefficients of constituents of *shisham* leaves ..	143·35	415·80	126·00	83·14	101·70	126·50

Digestibility Experiments.

Table V.

Feed .. .. *Bhusa* (from wheat) alone.

Animal .. .. Nila.

Period .. .. 23rd January to 4th February, 1923.

Bhusa eaten .. .. 129 lb. = 118 lb. dry matter.

Dung .. .. 306 „ = 52·17 „ „ „

Digestibility coefficient of *bhusa* = 55·78 On dry matter.

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	8·54	91·46	7·08	0·740	41·36	3·70	37·85
Dung	82·95	17·05	2·64	0·175	6·09	1·00	6·97

Actual quantities of different constituents.

In *bhusa* given ..	..	117·98	9·13	0·955	53·36	4·77	48·83
In dung voided ..	..	52·17	8·08	0·536	18·64	3·06	21·33
Bhusa digested (by difference) ..	..	65·81	1·05	0·419	34·72	1·71	27·50
Digestibility coefficients	..	55·78	11·50	43·87	65·65	35·84	56·31

Digestibility Experiments.

Table Va.

Feed	..	..	*Bhusa* (from wheat) alone.		
Animal	..	..	Mina.		
Period	..	..	23rd January to 4th February, 1923.		
Bhusa eaten	..	..	127·5 lb.	= 116·60 lb.	dry matter.
Dung	..	..	243 „	= 45·36 „	„ „
Digestibility coefficient of dry matter				61·10	

Analytical composition.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa	8·54	91·46	7·08	0·740	41·36	3·70	37·85
Dung	81·33	18·67	3·07	0·185	6·02	1·12	8·04

Actual quantities of different constituents.

In *bhusa* given ..	..	116·60	9·03	0·944	52·73	4·72	48·26
In dung voided ..	..	45·36	7·46	0·450	14·62	2·72	19·54
Bhusa digested (by difference) ..	..	71·24	1·57	0·494	38·11	2·00	28·72
Digestibility coefficients	..	61·10	17·38	52·32	72·26	42·36	59·51

Digestibility Experiments.

Table VI.

(*a*) *Analysis of bhusa* (*from wheat*), 1922 *and* 1923.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Bhusa 1922 ..	5·71	94·29	7·58	0·72	39·87	1·72	44·40
Bhusa 1923 ..	8·54	91·46	7·08	0·74	41·36	3·70	37·85

(*b*) *Albuminoid ratio and starch equivalents of different feeds used.*

	Albuminoid ratio	Starch equivalent or food units
Wheat *bhusa*, 1922 .	1 : 43·04	50·50
Wheat *bhusa*, 1923 .	1 : 10·68	48·95
Gram .	1 : 3·49	113·64
Maize	1 : 8·86	106·43
Shisham leaves .	1 : 3·18	29·27

Digestibility Experiments.

Table VII.

The nutrition of Farm Animals, by Henry Prentiss Armsby, Ph.D., LL.D., (*page* 115), 1917.

	Moisture %	Dry matter %	Ash %	Ether extract %	Crude fibre %	Protein %	Nitrogen-free extract %
Analysis.							
Hay	15·03	84·970	5·490	2·290	28·610	10·240	36·980
Fæces	77·64	22·360	1·920	0·520	9·290	3·130	7·500
In hay eaten ..	..	3·144	0·203	0·085	1·059	0·379	1·368
In fæces excreted ..	..	1·267	0·109	0·030	0·526	0·177	0·425
Difference-digested ..	..	1·877	0·094	0·055	0·533	0·202	0·943
Percentage digestibility.	..	59·70	46·48	65·02	50·27	53·19	68·94
Mina.							
Bhusa 1923 (wheat *bhusa*)	8·54	91·46	7·08	0·740	41·36	3·70	37·85
Dung	81·33	18·67	3·07	0·185	6·02	1·12	8·04
In *bhusa* given ..	..	116·60	9·03	0·944	52·73	4·72	48·26
In dung voided ..	..	45·36	7·46	0·450	14·62	2·72	19·54
Bhusa digested (by difference) ..	..	71·24	1·57	0·494	38·11	2·00	28·72
Digestibility coefficients.	..	61·10	17·38	52·32	72·26	42·36	59·51

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